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EDITORIAL

Microplastics and Human Health: Confronting the Hidden Tsunami

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Introduction

Global plastic production has increased dramatically over the past two decades. Between 2000 and 2020, global plastic production rose from 234 million tons to 435 million tons, and may increase by nearly 70% by the year 2040, reflecting a rapid expansion in manufacturing and consumption. Plastics are synthetic materials of polymeric compounds such as polyester, polyethylene, polypropylene copolymers, and polyurethane which are frequently combined with different additives to enhance performance characteristics such as durability, flexibility, and resistance to heat or ultraviolet radiation [1].

Plastic materials comprise of a large number of chemical substances and approximately over 13,000 chemicals are involved in production and processing of plastic. Among these chemical substances, a few categories of chemicals have been identified as particularly attention due to their toxicity and their potential to leach or migrate from plastic products into the environment. These high-priority groups include certain flame retardants, UV stabilizers, per- and polyfluoroalkyl substances (PFAS), phthalates, bisphenols, alkylphenols and their ethoxylates, biocides, metals/metalloids, and polycyclic aromatic hydrocarbons. Many of these chemicals are known for their persistence in the environment and potential adverse effects on ecosystems and human healthcare system, which has raised growing global public health concern regarding the chronic impact of plastic production and usage [2].

Microplastics

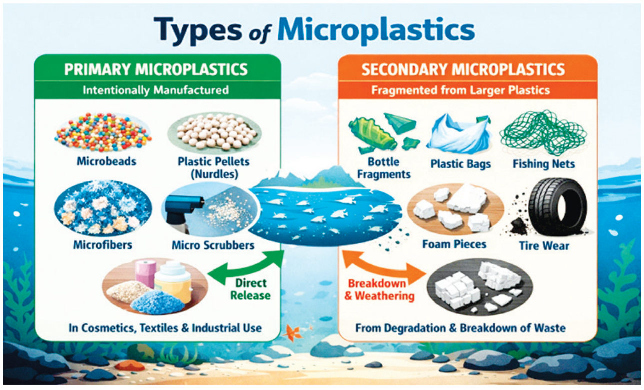
Microplastics referred to plastic particles size of less than 5 mm in diameter. These particles originate from the breakdown of larger plastic debris in the environment and it can enter into the human body through inhalation or ingestion. Specifically, very small airborne particles of 2.5 ìm or less in diameter are capable of reaching the lung alveoli, entering the bloodstream, and subsequently distributing to different tissues in the body [3]. In addition to airborne exposure, microplastics have been detected in a variety of food items, beverages, and drinking water sources, allowing them to enter the body through dietary intake.

Evidence of microplastic contamination in beverages has also been documented. A study conducted in Mexico in 2020 examined 57 commonly consumed drinks, including soft drinks, beer, iced tea, and energy drinks. Detectable microplastics were found in 48 of these samples. Among them, 36 beverages contained fewer than five particles per liter, nine samples contained between five and ten particles per liter, and three samples contained between eleven and thirty particles per liter. The highest concentration was observed in a beer sample, with an average of 28 particles per liter [4].

Microplastics are also present in several everyday consumer products such as clothing, cosmetics, and personal care items. The use of these products may increase human exposure through accidental ingestion or inhalation of airborne particles. A systematic review published in 2024 analyzed 38 studies covering 2,379 cosmetic and personal care products and reported that approximately 16.4% of the products contained microplastics. Face scrubs were the most frequently examined products in the review, accounting for nearly half of the tested items, and about one-quarter of these scrubs were found to contain microplastic particles [5].

The structural characteristics of microplastics, including their irregular shapes and relatively large surface area, allow them to function as carriers for a wide range of environmental contaminants. These particles can adsorb or absorb pollutants through hydrophobic interactions, electrostatic attraction, or pore-filling mechanisms. As a result, microplastics may accumulate and transport harmful substances such as microorganisms, polycyclic aromatic hydrocarbons, and heavy metals.

Experimental studies using human cell cultures, organoid models, and animal systems have demonstrated that exposure to microplastics can trigger several biological effects. These include increased oxidative stress, excessive generation of reactive oxygen species, damage to cellular membranes and organelles, activation of immune responses, and potential DNA damage. In laboratory studies using liver organoids, exposure to polystyrene microplastics produced signs of liver toxicity. This was indicated by increased levels of liver enzymes such as alanine aminotransferase and aspartate aminotransferase in the culture medium, along with disruption of antioxidant balance. Even at low concentrations, microplastic exposure was associated with oxidative stress and inflammatory responses, reflected by elevated levels of interleukin-6.



Analytical techniques used for measuring microplastics

Several analytical techniques are currently used to identify and measure microplastics in environmental and biological samples. Commonly applied approaches include microscopy, spectroscopic methods—which analyze the light absorbed or emitted by substances—and thermal analytical techniques [6]. A large proportion of existing studies have primarily focused on identifying polystyrene microplastic particles.

Although many of these analytical procedures have been developed, validated, and described in scientific literature, important challenges remain. One major limitation involves the difficulty of isolating microplastic particles from complex environmental or biological matrices, such as water, food, or tissue samples. In addition, accurately distinguishing between different types of plastic polymers can be technically demanding.

Because of these challenges, ongoing research is aimed at developing more reliable, standardized, and sensitive methods for detecting and quantifying microplastics. Improved analytical techniques are essential for ensuring accurate assessment of microplastic contamination and for facilitating comparisons across different scientific studies.

Microplastics in Human Tissues

Microplastics have been identified in several human organs and biological samples, including the lungs, brain, blood, liver, kidneys, heart, spleen, colon, testes, ovarian follicular fluid, placenta, breast milk, and even in newborns' first stool. Research over recent decades suggests that the concentration of microplastics in human tissues has gradually increased. For example, a comparison of post-mortem samples showed higher levels of microplastics in individuals studied in 2024 than in those examined in 2016, particularly in brain and liver tissues [7].

Health Effects Associated with Microplastics

Several observational studies have suggested a link between microplastic exposure and adverse health outcomes, although a direct causal relationship has not yet been firmly established. In one investigation involving 257 individuals with asymptomatic carotid artery disease, polyethylene microplastics were detected in carotid artery plaque samples in 58.4% of patients. Additionally, measurable amounts of polyvinyl chloride were identified in a smaller proportion of the samples. Individuals whose arterial plaques contained microplastics were found to have a substantially higher risk of major cardiovascular events—including myocardial infarction, stroke, or death—during a follow-up period of approximately 34 months compared with those in whom microplastics were not detected [8].

Evidence from post-mortem studies also suggests a possible association between microplastics and neurological conditions. Brain tissue samples from patients with dementia were reported to contain significantly higher concentrations of microplastics compared with samples from individuals without dementia. Although these findings highlight potential health concerns, further research is required to better understand the biological mechanisms through which microplastics may contribute to organ dysfunction and disease.

Experimental and observational evidence suggests that MPs disrupt metabolic pathways (causing insulin resistance and â-cell dysfunction), and may enhance carcinogenesis through genotoxicity, epigenetic alterations, and chronic inflammation [9].

Regulation to Reduce Plastic Pollution

Various local and national regulations have been introduced to address plastic pollution; however, comprehensive global agreements remain limited. Some international measures have been implemented to manage plastic waste and reduce its environmental impact. For example, the **2019 Basel Convention Plastic Waste Amendments** [10] regulate the cross-border movement of plastic waste, particularly preventing its transfer to countries that lack adequate recycling infrastructure or technical capacity to manage plastic waste safely.

Another important international regulation is **MARPOL Annex V [11]**, a legally binding agreement adopted by more than 150 countries. This convention prohibits ships from discharging plastic waste into the oceans, thereby aiming to reduce marine pollution caused by maritime activities. In addition, global efforts are underway to develop stronger international frameworks.

On August 18, 2024, in New Delhi, the Food Safety and Standards Authority of India (FSSAI) initiated a project to address the rising concern of microplastic contamination in food. The initiative, titled **"Micro- and Nano-Plastics as Emerging Food Contaminants: Establishing Validated Methodologies and Understanding the Prevalence in Different Food Matrices,[12]"** began earlier in March 2024. Its objective is to develop and standardize reliable analytical techniques to detect micro- and nano-plastics in food items and to evaluate their occurrence and potential exposure levels within the Indian population.

Conclusion

The detection of microplastics in various human tissues has become increasingly common, reflecting the expanding presence of plastic contaminants in the environment. Emerging evidence suggests that exposure to these particles may be linked to potential health risks, although the full extent of their impact is still being investigated. The widespread contamination of air, water, and soil with plastic debris underscores the urgent need for coordinated global efforts. Strengthening international policies, improving waste management strategies, and developing safer, environmentally sustainable alternatives to conventional plastics are essential steps to reduce plastic pollution and protect both environmental and human health.

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